Jennifer Stock: You're listening to Ocean Currents, a podcast brought to you by NOAA's Cordell Bank National Marine Sanctuary. This radio program was originally broadcast on KWMR in Point Reyes Station, California. Thanks for listening!

(Musical Intro)

Jennifer Stock: Welcome to another addition of Ocean Currents, I'm your host, Jennifer Stock. On this show we talk with scientists, educators, explorers, policy makers, ocean enthusiasts, adventurers, advocates, and more, all uncovering and learning about the mysterious and vital part of our planet, the blue ocean.

I bring this show to you monthly on KWMR from NOAA's Cordell Bank National Marine Sanctuary, one of four National Marine Sanctuaries in California, all working to protect unique and biologically diverse ecosystems.

Last week I had the great opportunity to lead a group of teachers on a fieldtrip at Gulf of The Farallones National Marine Sanctuary, as day two of a professional development workshop. And we were really lucky to enjoy the islands, the birds. Birds are out there right now, lots of breeding plumage, very busy in the water, lots of fish in their bills. It was just a really exciting time to be out at the islands. And we were also treated to having seen four blue whales, so the water is hopping right now. All of this is east of the islands, and we were treated to seeing krill on the surface of the water as well. So perhaps the whales were feeding or checking it out to feed, it was really pretty awesome.

We have talked a bit about whales on this show in the past; most recently we talked about large ships hitting whales. The shipping lanes have been adjusted, taking into account what we know about whales feeding locations. And actually just earlier today a new ap was released which allows boaters to document where they are seeing whales, and further allowing researchers to see where endangered species are, and if they are indeed in shipping lanes, then notices can be sent out to mariners. So there is some good progress to date.

However, since whaling has ended Humpback Whales have rebounded in numbers, but Blue Whales have not, and it's been speculated that this is due to their proximity to shipping lanes and the potential to be hit by ships. Researches predict that for every certified ship-stricken whale that washes ashore there are many more undocumented whales, hit out at sea.

So this brings up the question- what happens to a whale when it dies of natural causes, or from a ship strike? Some do wash ashore, or become a specimen for marine biologists to study? Whales are difficult to study in general. A whole lot of data about whale physiology- disease, age, gender, can be gained by doing an autopsy on the animal at the beach. But most animals end up in their own habitat, in the ocean, and eventually sink to the sea floor. And so this makes for a very interesting lesson in decomposition. Everything that's alive dies, and an animal of such large proportion provides an interesting opportunity for study.

So my guest today works at the Monterey Bay Aquarium Research institute, also known as MBARI, and is participating in studies surrounding these unique communities. Shannon Johnson is a research technician at MBARI, and works on genetics and phylogenetics in deep-sea species. She earned her masters in marine science from Moss Marine Lab, and is live on the phone with me today. Shannon, welcome, you're live on KWMR.

Shannon Johnson: Thank you very much!

Jennifer Stock: Thanks for tuning in.

So I imagine on a hot day like today, studying a dead whale on the beach would not be as comfortable as studying a dead whale from a ship in a Remotely Operated Vehicle. What do you think?

Shannon Johnson: (laughs) well, they never smell good. When we're in the ocean we pick up piece of bone, so we can study the animals that live on them, and they stink really bad there too. So (laughs) we're kind of notorious for bad smell in our lab.

Jennifer Stock: I guess it kind of goes with the territory. So, tell us: how did you get into this area of study?

Shannon Johnson: Well it was kind of an opportunitistic endeavor. Our group was out in 2002 working on a cold seep. A cold seep is kind of a slow leaking of nutrients out of the sea floor. It can be like a kelp raft that gets buried, and then starts rotting, and that feed the chemosynthetic community, and typically, especially in the Monterey Bay, we have these clams that live in the deep, and they're really cool. Big beautiful clams. So we were out looking for these clams in about 3,000 meters of water of Monterey Canyon, and on the way to the canyon, we were exploring the area, we came across this big skeleton, and it was so cool, because watching the video, you just watch this big, white, beautiful whale emerge in the darkness, and on the bones of this whale were these glowing red things. And, you know, at first glance you didn't see them, and then as you got a closer look at the whale, you could see that it was covered in this…it was almost like feather boas, and tiny little feather boas all over the whale. And so they picked up some bones, and that's how we started on whale fall ecology and deep sea…

Jennifer Stock: So it's called a, "whale fall community," and that's basically a whale that's fallen to the sea floor.

Shannon Johnson: Yeah, and all the critters that eat it.

Jennifer Stock: Could we back up a second, you mentioned the word, "chemosynthetic community" and I know this is a key word we are going to be talking about throughout the show- can you describe what a chemosynthetic community is, you were originally talking about the cold seep habitat.

Shannon Johnson: Yeah, and actually any reducing environment, there's actually thermal vents, there's cold seep, even wood can provide some sort of chemosynthetic community, that's basically what I'm taking about. Back in the 70's we thought all of the energy in the world came from the sun, from photosynthesis, and then geologists went to hydrothermal vents deep, deep in the ocean, near the Galapagos islands, and they found vents, and they saw these giant, beautiful,

four foot tall tube worms, and huge mussels and clams, and saw this amazingly diverse community of invertebrates that were living where there's absolutely no light at all, and no apparent input from the sun. And even geologists were excited, and it's hard to get geologists excited about anything other than rocks.

Jennifer Stock: (laughs)

Shannon Johnson: And so they brought up animals and took them to the appropriate biologists, and discovered a whole new energy source, which is chemosynthesis. So it's basically bacteria feeding off minerals, hat are coming out of the sediment, or the vents or the whale or whatever, and then feeding other animals, they can either live with the bacteria symbiotically, with a specialized structure within their bodies, or they can graze it, or eat other animals that have a symbiotic relationship with chemosynthesis. And that kind of derives this whole community, and they're kind of like islands of food, because the deep sea is generally pretty depoperate of food, and so when you have these reducing environments, you have a good collection of really neat stuff living there.

Jennifer Stock: Yeah, it's like a little laboratory in itself. So you found this whale, and you probably took a few samples, what were some of the questions that came to mind for the research team regarding the community in general, and what those worms were?

Shannon Johnson: Yeah. So the first collection, we called them the "green snot worms," luckily our group worked in genetics of these animals in these reducing environments, and in the ocean, doing population genetics especially, is kind of tricky because there aren't so many boundaries in the ocean as there are on the land, right? There are mountains, and rivers, and things that could separate things, and could allow for genetic distinction, but in the ocean it's more well mixed than in terrestrial environments. So my group has typically focused on these reducing environments because they're typically like little islands full of animals.

And so we've already worked on hydrothermal vent worms, and so when they picked up the bones and saw these red, beautiful, boa-looking feathered worms all over it, they thought, " Oh, these look

a lot like the hydro-thermal vent worms Riftia. Riftia Pachyptila are these big worms, they can be a meter tall. They are very simple, they have a plume for gas exchange, and their plumes are really quite beautiful, they really do look like a big feather boa, they have a trunk, and then they have a specialized structure inside of them, called a trophasome, where they house their bacteria, And they do have a mouth, they don't have a gut, nothing else. Very simple. And these worms that were all over the bones of the whale looked just like that. But what was interesting was that there was not much flesh left at all, there were some guts left, but these worms were very obviously living on the bones. Not off of the tissue that had been there.

So what was interested us about these worms is they almost have this root structure, they were almost like plants, and they extended down into the bones. One thing that's really fabulous about our lab is we have great collaborators, and so knowing we do the genetics, and not the morphology or taxonomy, we called our friend Greg Rouse, and at the time he was at the south Australian museum, and he's like the world's expert on worms, if you need to know about a worm you call Greg. And so we sent him some samples, and he did the morphological description, and Shauna did all the genetics, and they identified the bacterium that feeds the worms. And all those people together described the worm and they called it, "Osedax," or bone eater.

Jennifer Stock: And this is a new species, right?

Shannon Johnson: This is a new genus and new species, and really a new energy source. I think there are some birds, some lammergeiers that eat bone, and some wild dogs that eat bone, but just as kind of by catch? There aren't any other animals that I know of whose diet is primarily just composed of bone.

Jennifer Stock: That's amazing.

Shannon Johnson: Yeah!

Jennifer Stock: So, coming back. That's probably at a very late stage of the whale's decomposition, and I wonder, what are the stages earlier

on? I know that some sea birds pick at dead whale when it's on the sea's surface, but then it starts to float down to the sea floor. What are some of the some of the earlier stages of decomposition, what other animals are attracted to a prey source like that on the sea floor?

Shannon Johnson: Well, that's a great question, and we didn't know. This wasn't our field. This wasn't our deal. There are people who have been working on whale falls for a long time, and they have mapped out specific stages of these whale falls.

So there's this first scavenger stage. Like you say, the birds and the sharks come, and then they got to get the whale to sink, and we learned more about this as we went on. You know, the whale we found was pretty advanced, and it had decomposed very quickly. We went out a few months later, when we first initially found it, and the pelvic girdle was completely gone, it was like it had melted into the bottom of the ocean already. And this was a very exciting discovery- new genus of new species of totally weird worms, and we knew we had a whole lot of work to do to even understand how these worms were even doing this…so we started sinking whales.

And so that's one thing about living along the Monterey bay, and along lots of shipping channels, and also I think we have more casualties, due to orcas, they will separate momma and baby whales and rip the jaws off the baby whales, and eat their tongues. Which is kind of a horrible sad thing to watch, I'm glad I haven't had to see it, I've only seen the results of it, you get these little juvenile whales washing up on the seashore with no lower jaw and no tongues.

Jennifer Stock: Mmm

Shannon Johnson: So we would take these baby whales back out, we would ventilate them, you can use your imagination how we do that. And then drag them back out to sea, and then sink them, and we've sunk them at a bunch of different depths, which has allowed us to see the different stages.

The scavenger stage, where all sorts of cool things come in, like crabs, and sharks, we've seen a six scaled shark, feeding on the whale carcass, and lots of hag fish, really disgusting, squirmy. Thousands and thousands of hagfish. You know, I like study worms, and really like snails and stuff, and hagfish gross me out.

Jennifer Stock: (laughs)

Shannon Johnson: They're gross, gross animals, And in a good way, but gross!

Jennifer Stock: How long is that mobile scavenger stage, you were mentioning earlier that it happened so fast; it's like a couple months? Is this a year?

Shannon Johnson: Months at the most…

Jennifer Stock: Wow!

Shannon Johnson: I'm thinking all the flesh is gone from the whale within the first month, and it goes fast. And it's an amazing amount of tissue that's there too.

So, in next stage this bacterial matte seems to form, at least for us. And this differs in different places, and this is not what the people who've studied whale falls for a long time have seen, So we were surprised how fast this whole process went. So a few months and all the tissue is gone, there's still hagfish, there's always hagfish around looking for lunch, but then we get this big dense bacterial matte form, within the first few months. And the Osedax, the blindworms, come in and colonizes the carcass. And then what has typically been seen in other whale falls, if the Osedax are not there, the whale carcass will go into this reef stage, and they used to estimate that reef stages could last 50-100 years! And that's not at all what we've seen.

And we've relabeled the Osedax as almost a keystone species because it degrades the carcass so quickly that it actually drives the ecology of the community. Because it actually disappears the skeleton so quickly.

Jennifer Stock: That's amazing, and so in some other areas of the world, in the ocean there's a reef stage, and there aren't any worms decomposing the bone?

Shannon Johnson: Yeah! And so a lot of the work that has been done on other whale falls in the Santa Monica, off, you know, the Santa Monica Bay, and it's a pretty low oxygen, and we actually just had a cruise down there earlier this year, and it was kind of neat because we got to go see a whale that our colleagues had sunk at Scripps, and that was off San Diego. And then a couple days alter our other colleagues that were on the leg before us, bumped into a whale skeleton, and this doesn't happen very often at all. It's happened 2 or 3 times for us now, but we've spent a lot of time looking at the bottom of the ocean, and we've tried to use all kinds of tool to image the bottom of the ocean to look for whale falls and it is not easy, the best way to find them is to put them there and to know where you put them.

Jennifer Stock: Go it.

Shannon Johnson: But they very opportunistically bumped into another whales fall but the oxygen levels were so low…the typical wave we use to measure oxygen are an optode, and a couple different instruments on an ROV, and it was so low that the instruments weren't able to measure it, but the group there with us was there with much more fine scale instruments and they were able to say that, yes, there was oxygen there, but incredibly low. And there were no worms, which was interesting. It seems like if the oxygen is too low they wont colonize.

So a lot of the work has been done in that same basin, on whale falls, and so a reef stage for 50-100 years seems pretty conceivable because, you know, there's not a lot around to eat it.

Jennifer Stock: Wow, Wow!

For folks tuning in, you're listening to Ocean Currents, and my guest today is Shannon Johnson, research technician specialists with the Monterey Bay Aquarium Institute, and we're talking about the very interesting whale fall community on the seafloor.

And it's fascinating because even though I know things die, and I talk a lot about upwelling, and how the nutrients on the seafloor are brought up the surface to help fertilize the phytoplankton, and this is just another source on nutrients, but it's also a wonderful example of how nature recycles itself. I mean, OK, the whale has died, but there are so many critters that have benefited from that input of food to the seafloor. It's just a really interesting ecological story that we don't really think about much, but it caught my attention and I wanted to learn more about it, so we're thrilled to have Shannon on today.

Since these whale falls are nearly completely random, yes, some of them are human induced through ship strikes, but others come about though natural causes, and these species on the seafloor are spread out all over the place as well…how many of these species are just waiting for a whale fall, and how do they find it?

Shannon Johnson: (laughs) Oh, that's a very good question. So the cool thing about the Osedax is…well, the first thing is sinking a whale is super expensive, you have to spend a whole day of ship time, and ship time is not cheap. And so we started experimenting with different types of bones, things we could get more affordably, like cow bones, and pig bones, and we have some elephant seal bones out there, and it turns out the Osedax will colonize any bone, even turtles and fish, the only thing we haven't gotten them to colonize is shark cartilage and that's just because it disappears too quickly. They'll live on any bone.

Not too long ago, before humans were killing everything, there were a lot more whales on the scene, and so this didn't used to be such a risk life history strategy, there were more big things swimming around in the ocean. There are quite a few species of Osedax, we're up to 20 species in the Monterey Bay alone, and they've been found all over the world, now that people know what to look for, people are sinking whales and finding them everywhere. At all depths too, there are shallow water species Osedax, and anarcticus, which is really cool.

Jennifer Stock: (laughs)

Shannon Johnson: So what we think happens is they have a typical polychaete larvae, which is a little worm larvae, called a trouckfour, and they're very fecund, we have a really cool video. These guys will pick up a bone, and you know a lot of invertebrates, the moment you start picking on them, they'll spawn, because they're like "Oh my gosh, I'll going to die!" And so it's their last little clutch for continuing their species. So we'll pick up the bone and we'll hold it right up to our cameras and video them, and they'll spawn. And you can actually see them spawning on the video. And so we think they broadcast their colony out into the water, and we just think that there's a ton of them and I think there's some sort of settlement cue with the bacterial mat.

Jennifer Stock: Ah, interesting.

Shannon Johnson: So there are some others that will settle upon getting a cue from their parents or their reef of whatever. And what we think happens, I haven't even told you the coolest thing about these worms: all the biggest worms we find….are female!

So Greg looked and looked and looked, and every worm he looked at was female, and he could tell they were al female because they all had eggs, and there was no evidence of sperm storage or hermaphodidi… I can never say this word, they were not hermaphrodites so finally, after very close observation of their tubes, he found what looked like very little larvae in their tubes, but they had sperm. And the females have harems of dwarf males living in their tubes.

Jennifer Stock: (Laughs) that is crazy!

Shannon Johnson: And the best thing about these worms is the bigger they are, and the older they are, the more males they get, this is definitely a case where women win.

Jennifer Stock: Amazing, that's just an amazing life history strategy, in terms of reproduction. Do any other species do something similar to that?

Shannon Johnson: There are! There are some dwarf males, the worm called Bonellia, and they have little dwarf males, and females actually produce

masculinizing hormones, that masculinizes the larvae, and turns them into males, and we think that something like that must go on with the Osedax, because we can actually see them acquiring males. And so we had a, we were curious about the males, we wanted to know, were they the sons? Are they brothers? Because you know, females can have several hundred males in their tube. And the males don't live off the females, they aren't parasites, they just use up their yolk reserves, from being larvae, and produce sperm, and then they just turn into these little ghosts.

So we did the genetics to make sure they weren't brothers, and sons, and it's a random draw of the population. And so what we think happens is the first cloud of larvae finds the whales, and settles out based on some bacterial from the bacteria mat, because we don't see settlement until we see the bacterial matt. So the first comers are female, and they start growing, and then they start accumulating males, and then they start spawning,

Jennifer Stock: Someone's got to do a science fiction film on these worms. It's pretty amazing. Get Pixar on that!

Shannon Johnson: (Laughs)

Jennifer Stock: That's so interesting, and the whale feeds on the whalebone, it basically shoots down these roots into the bone. And that must be challenging itself, I mean it's this invertebrate, it's so small and thin, and I'm imagining whalebones to be really dense, how do they penetrate that bone?

Shannon Johnson: Great question! Certain species of Osedax, when you dissect the bone around them it's like mush! Other species they kind of bore this hole in, and I can't get in, I mean I've broken so many forceps trying to get these guys out, and it takes forever. I mean, we see that species and we're like we all kind of make a collective groan, "Oh nooo! Not Osedax Roseus!"

Jennifer Stock: (Laughs)

Shannon Johnson: But then, like Osedax Frankpressi has these big, fat, juicy roots, and the bone is like snot. So Greg Rous, and another researcher at

Scripps, and Sigrid Katz, just published a paper about how they're invading the bone, and the worms actually produce acid to erode the bone, it's so cool. They actually turn themselves into a proton pump, and create acid so they can get down into the bone.

Jennifer Stock: Amazing, what an interesting animal,

Shannon Johnson: And the more the worms, the snottier the bone.

Jennifer Stock: So, I imagine this happens rather fast,

Shannon Johnson: Pretty speed, yeah. And like I mentioned, different species have different root structures, and have different methods of doing it, and it's really cool, like when you get the right species it's so easy to dissect them out, you get these beautiful specimens,

Jennifer Stock: So when the whalebone has completely fallen apart, you said it just turns into mush, perhaps on the seafloor, barely resembling a whale structure, what happens to the Osedax worm?

Shannon Johnson: Well, luckily they are fecund and they live reproduce, and hopefully they move one to find another whale. So, we've sunk five or six whales in the Monterey Bay and from 300 meters to 1800 meters, and we've found 20 species. We've started out with two species, they were' the opportunistic ones at the deepest levels, but now we're up to 20. And on the cruise we just went on in southern California we found many of the species that we already have. In fact our boss at one point would say, "don't find anew species." Because every time we would go out we would find a different species, and we'd go running down to his office like, "There's another one!" "No! We have so many to describe!"

Jennifer Stock: Ha, that's amazing, because then you have to go through the whole process of having the species recognized.

Shannon Johnson: Yeah, and so far we've only done three. (Laughing) we have a lot of work to do.

Jennifer Stock: So this whole whale fall community, it's really all about the worms.

Shannon Johnson: It is. But! A cool later stage that we've found is a bone eating snail, and like you say, the Osedax break the bones up into these little bits and then we found a new genus, and two new kinds of bone eating snails, they call them Rubyspira Osteovora and Rubyspira Goffrediae, after Shauna Goffredi, who's a good friend and also one of the main researchers on all this work. But these guys are actually really interesting because they actually grind down the bone. Osteovora is actually a big snail and there are tons and tons of them! Thousands of them on our deep whales. And we published an ecological paper in 2005 or 2006, and all these paleontologists called and asked, "Where do you get those snails? They look extinct, they look a lot like the fossils" (laughs)

Jennifer Stock: Wow.

Shannon Johnson: Yeah, so since then we did some molecular work, in which I made a molecular clock to see if these guys are true living fossils of this species that's hundreds of millions of years old, or if they just represent the lineage that just looks like this fossil.

So there's this cretaceous fossil, it's called Atresius Liratus, it's about 130 million years old, and it's pretty remarkable it looks just like them when you hold the picture of the fossil up next to the picture of the living snail. And you're like, "Yeah, that's that guy!" But you know, mollusks can look a lot alike, and be very different.

Jennifer Stock: Right, there is so much work that needs to be done beyond that

Shannon Johnson: Right. So really these guys are a relatively young species, probably about 35 million years old, so they're not the same guy that lived on the seep, but they are representatives of that lineage. But the Osteovora pick up the bits of bone that are down in the sediment and eat them, and they have these little stones their guts, so it's kind of like how a crop uses a gizzard to grind down the bone and then eat it, and then digest it whereas the Goffrediae actually sit up on top of the bone and scrape little bits off with their radula, which is kind of like a snails throat, or tongue type thing, slash gizzard, it's actually really ground down on the Goffrediae, whereas the

Osteovora just looks like it used the rodula to pick up little e bits of bone. So, really cool.

So, you asked me earlier about what things are just whale things, and all though these things will eat other kinds of bones, obviously the whale is probably the best meat market these is.

Jennifer Stock: Best food, nutritional source I guess.

Shannon Johnson: Yeah, longest term thing, anyways.

Jennifer Stock: Well Shannon we need to take a quick break, so please stay on the line.

For those of you tuning in, this is Ocean Currents, and I've been talking with Shannon Johnson, from the Monterey Bay Aquarium Research Institute, and we're talking about the whale fall community. When a whale dies, it falls to the sea floor, and a wonderful world takes over in its decomposition, so we've been talking about some of the fascinating species that take part in that process. We're going to take a quick musical break and be back in a little bit. You're tunes to KWMR 91.5 Point Reyes station, 89.9 Bolinas.

(Musical Interlude)

Jennifer Stock: And welcome back, this is Jennifer Stock, you're listening to Ocean Currents. Today I have Shannon Johnson on the line, from the Monterey Bay Aquarium Research Institute, and we're diving into the deep-sea ecology of whale fall communities, what happens to a giant whale when it dies and falls to the seafloor? There's an amazing amount of things happening in the decomposition of this whale. Shannon has been describing some amazing worms, the osedax, and also this snail that seems like something that was extinct.

We're back on the air, thanks for sticking with us.

Shannon Johnson: No Problem.

Jennifer Stock: So I wanted to go back to this snail thing, so they think it's a relative of a snail that they thought was extinct, which poses an interesting question about animals that are potentially still around from way back when dinosaurs roamed the planet. What other questions did that bring up in terms of these communities, are there evolutionary stories they might be able to tell based on the discovery of this species?

Shannon Johnson: That's a great question. You know when everyone started working on vents it was thought that, "This is where life began." And in fact we have archaeogastropoda, in all sorts of these families and names of animals from the deep sea and that's kind of a remnant of this thinking. And it turns out most stuff in the deep sea is quite young. And we tried, especially with the snails, the Rubyspira, the group that they are associated with is called the abyssochrysoidea, and the oldest members are probably some of the shallowest members, and that is the oldest group we can push back most everything in the deep sea, is quite fragile, and it turns out that the paleocene–eocene thermal maximum was what, 55 million years ago? And that was associated with a huge anoxic event and so it's very hard to find anything from the deep sea that extends before that event, and so, life may have begun in the deep sea, via chemosynthesis, but certainly the things living there now are not ancient at all. And they're much younger than shallow water things.

Jennifer Stock: Oh, I see. Very interesting. That just recently came up, I was attending the ocean acidification conference in Monterey and it sounded as if there was a massive die off with ocean acidification and we're headed towards levels that are much higher than that event that really wiped out a good amount of biodiversity on our planet. It's interesting thinking about these massive events and what happens and then the changes that occur and what is around still, and some of it we don't even know in the deep sea, and we're just discovering, it's amazing.

Shannon Johnson: Yeah, and people for so long thought the deep sea was protected because it is so far removed from shallow water, but the physical constants down there, like the temperature and the oxygen and the salinity, all the physical constants are very uniform and very

protected, even the hydrothermal vents. I'm working on some groups from the same family that the snails are from, and they live, essentially, in hot acid, OK? But the only thing that they are really sensitive to is oxygen levels, and if the oxygen levels drop, they are out of there; they're not there. You can't find them. But they live in hot acid. You know, I was thinking, "these guys are going to be our bright shining samples with climate change, these guys will be the sample, but oxygen is the limiting factor, nothing is going to do too well without the oxygen.

Jennifer Stock: Right. I want to step back and ask a big picture question, with climate change, and the changing climate everywhere. Sea surface temperatures, air temperatures, everything. What are the impacts that are being thought of for the deep-sea environment? Because, ultimately, things in the deep sea are being influenced by the surface. So what are some of the deep sea changes we might be seeing?

Shannon Johnson: Well, this is definitely a bit out of my realm, but everything we've seen so far is really fragile, so that's one thing we've noticed a lot is that big changes are not good in the deep sea. I mean shallow water, like a mussel, a mytilus; let's think about a mytilus for a second, it can see a 40-degree temperature change in a day. It can see a huge change in salinity if it gets a little bit of rain water on it, And they're going to be OK, they deal with hot, they deal with cold, they can do starvation. The deep-sea animals, they don't get to experience those things, so they have not adapted, and they are also relatively young, so they have not had time to adapt to these sever changes. So I have no idea how these things will react to climate change, but some researchers at MBARI have been doing some work and looking at high CO2 conditions on animals and nothing does well at all. Except for mobile things that can swim away from the experiment. So they guys that we work with that are fixed to the bottom are not going to be in their happy place.

Jennifer Stock: Hmmmm.

Shannon Johnson: And we work on things that live on such a different range, that go from hot thermal vents to 300 degrees Celsius, literally melting the minerals around them into the water, to cold seeps where, you

know, where you see very little change and you see very long term environments, especially compared to the vents, so we work on a really broad range of animals, but the universal limiting factor is oxygen, if it's too low they wont live.

Jennifer Stock: OK, that's interesting, and the other things I wanted to talk about, and we talked about that earlier; it seems like the species make up in each of these communities is similar, and they are kind of spread out across the planet- could the whale falls be thought of as stepping stones for this species, since they only really go to these specific environments?

Shannon Johnson: Well, that was an interesting hypotheses people brought up a while ago, it was a neat idea. Because yeah, you're right, the vents can be separated from hundred or thousands of kilometers, with huge ridges in between them, and seeps, which are even more randomly distributed than vents, and that these vent animals can ride along these long access line currents and then kind of go to the next vent, and then go to the next vent, and we have evidence from their genetics that they do this. And we are just starting to get into the genetics of the seep animals, and how they move around, but there are very few links of animals between vents, seeps, whale falls and woods there are more links between wood and whale falls, wood animals and whale falls. I think I found one limpet ever called lepetodrilus, and people used to call these animals "vent endemic," meaning they only live on vents, and we found one individual on a whale all the way up in Monterey, which was really weird, we don't know what he was doing there, but her was there. But there are some clams, some vesicomyid clams that can live on a late stage whale fall, and we actually found tons of these clams at the low oxygen whale fall in southern California, and we're just starting to see them show up at the Monterey whale falls, now that they've been down there for years. Basically it's a brown spot in the mud, and now the clams have come in as they've reached the fourth stage of what the whale falls ecologists have called the filamentous stage where the bacteria are now kind of producing all this sulfur and turning it into a seep, and so we are starting to see the clams show up in Monterey, but those are very few. I there's been one worm ever, one vestimentiferan, which are seep and vent worms, that have shown up at a whale fall. And so that's kind of a

sink, you know. One guy landed there and decided, "Well, maybe?" But it wasn't going to make it. So, there isn't a whole lot of support for that hypothesis, but it's kind of a neat idea, but we haven't seen a lot of true data supporting that idea.

Jennifer Stock: OK. So in terms of everything we've talked about today, some of the other stuff as well regarding the whale fall communities, from some from more of the biologists perspectives, what are some of the big questions that this information helps develop. Are there other scientific communities that can utilize this information?

Shannon Johnson: Well, I mean our labs main focus is really on evolutionary questions, how these things are getting where they're going, and how old they are, what did they how did they evolve to create this crazy life history. And this is where we get kind of hand wavy, like- how do you do try to calibrate molecular clocks, and it's like you use genes and fossils at different rates and try to guess how old these things might be but it's definite hand waving, and it's fun to tell a story that way.

Jennifer Stock: Yeah, well it's good to indentify the characters in a story.

Shannon Johnson: Exactly, exactly. And so big picture for the osedax? I mean there are two different rates we use, one based on deep-sea animals, and there's one based on worms. If we use the one based on worms, they are around 35 million years old, but if we use the deep sea one, the group is much older, like 75-80 million years old. And so 35 million years old sounds satisfying because that's about how long whales have been around, and the 75 million is a bit tougher because there's a big gap of time when these guys weren't able to live on any large mammals, seeing as all the dinosaurs went away 65 million years ago. So it's a big time frame, but they do live on fish and birds and things that did make it through. So, we don't know, that's hand waving.

Jennifer Stock: So a highly adaptable animal.

Shannon Johnson: Right, right, they'll live on anything. So, we don't know, but we can say, "maybe."

Jennifer Stock: (Laughs) so, you've got these whales, you drag them to a site to study them, and then, once they've completely decomposed, what happens? Are there going to be future questions about the make up of species, are you bringing in more mammals? What's the next step for Monterey's research community?

Shannon Johnson: Well, our group is kind of wrapping up the work we've done, we're doing a whole lot of species description, and thinking more about big picture stuff like what you're talking about. You know, our friends I mentioned before just published their paper on the acid, and there's a group in England looking at fossils, they're looking at where osedax trace in fossils, which is really cool. They're thin sectioning these bones, and are putting back together what would look like a root system, of an osedax in really old bones. It is kind of neat because this initial discovery has spawn all this research that people all over the world are looking at these worms, like a group in Japan at Jamstec sinking whales, they have a couple new species, but what's really interesting is that some of their species are the same as those in the Monterey Bay. Unfortunately we only have a few of those individuals that they have many of and vice versa. So, for doing population genetics across the ocean it's not going to work, unfortunately. But it's really amazing because there are very few trans pacific species in the ocean; there are a couple clams, and now these worms it doesn't happen very often.

Jennifer Stock: Especially traveling on the seafloor, I can imagine that's a pretty hard place to travel across.

Shannon Johnson: Yeah, yeah. And there are people in Sweden doing work on this, on bone worms, so there are people all over the world doing stuff with the osedax now, which is really neat, but we're kind of wrapping it up. We've done the easy part, (laughs) we'll let the other people answer the hard questions.

Jennifer Stock: Well, those are interesting questions to follow up on, I did see a number of other biologists involved in the work, University of Hawaii, and also down in san Diego.

Is there a website, or a link you can direct other listeners to see some of the video footage of these whale habitats, that's one of the beautiful things about MBARI is you have this fantastic remotely operated vehicles with wonderful video footage…and I imagine there's a link on line.

Shannon Johnson: Yes, there's a link on our website. You go to www.MBARI.org you can see lots of stuff and they are always putting up new video clips, and we should have some new stuff coming up off of our more recent cruise.

Jennifer Stock: OK. And you can also Google "EMBARI + whale fall" and get some really nice video. Because I did see a really nice video, it was like three or four minutes describing the community changing g from the flesh all the way down to the worms, and it was beautiful video footage.

Shannon Johnson: Yeah, I have to say, talking on the radio was kind of hard, because usually I get to talk with big beautiful pictures of flowing worms. (Laughs)

Jennifer Stock: Well Shannon, thank you so much for spending the day talking about worms, we don't talk about worms all that much, they're not the biggest mega fauna, compared to the whales and the sharks and the seabirds, but obviously they have an incredible ecological role, and it' really fascinating the evolutionary work that's going on in the genetics, so thank you so much.

Shannon Johnson: Well thank you so much for talking about worms.

Jennifer Stock: Ha. Only on Ocean Currents do you hear about worms. Awesome Shannon, thanks so much, have a great afternoon.

Shannon Johnson: You too.

Jennifer Stock: We have just been talking with Shannon Johnson from the Monterey Bay Aquarium research Institute, and we've been talking about the interesting ecology at the wale fall community when a large whale dies and is on the sea floor, and an amazing group of animals comes into decompose it. The MBARI group, the

Monterey Bay Aquarium research Institute, has been studying g the genetics of these animals and comparing them to other worms on other interesting steps on the sea floor, like at cold seeps and at hot deep sea vents. Fascinating stuff, the deep sea is just mind-blowing; it's like looking into outer space. Just a few follow ups regarding the deep-sea whale falls community. I found a few other facts regarding the importance of this research, like how deep sea animals react to point source enrichment, and for predicting the effect of potential relocation of sewage sludge, or disposing of other rich wastes at the seafloor. These factors provide new considerations, allowing us to consider how our decisions on land affect the deep sea.

Another interesting thing, and I didn't get a ton of information on this, is a San Diego company is working with a biologist to develop a cold water detergent that contains an enzyme found in bacteria grown on whale bones, which could potentially save enough energy to have an effect on a national scale. That's just another interesting consideration that spurs from the oceans biodiversity. There are some things that could really help us, and this could be an amazing invention. So, fascinating stuff.

Jennifer Stock: I wan to just say thanks for tuning in today to Ocean Currents. Ocean Currents is the first Monday of every month, and it's part of the West Marin Matter series, where you can tune in every Monday at one to learn about a topic of environmental focus. Ocean Currents has a podcast, you can go to iTunes, and search for Ocean Currents, or you can go to www.cordellbank.noaa.gov to get all the past episodes, just click under the "Education" link and you'll see all the shows there. And I love hearing back from listeners, do you have any questions, or great stories to share about the ocean? Please send me an email and I'll try to cover it on the next show. My email is Jennifer.stock@noaa.goc Thanks again for tuning in

(Outro)

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